Comparative analysis of human modeling tools

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Abstract

Digital Human Modeling tools simulate a task performed by a human in a virtual environment and provide useful indicators for ergonomic, universal design and representation of product in situation. The latest developments in this field are in terms of appearance, behaviour and movement. With the considerable increase of power computers,some of these programs incorporate a number of key details that make the result closer and closer to a real situation. With the differences in terms of performance, qualities, limitations, the choice of the tool becomes complicated in this wide range of possibilities. In this context, we propose to study and compare the most human modelling software available on the market, and thus provide an aided decision tool to help the designer to get the most adaptable tool.

1 Introduction

In the recent decades, emerged commercial software based on numerical models of man: the virtual human [1]. The Digital Human Modeling Software (DHMS) have been introduced in industry firstly to facilitate a faster design process [2]. With the increasing of computer power, the use of DHM software became unavoidable in the life cycle of products, where the design has to answer to end-user expectations, including their need for usability [3]. With an iterative process of product evaluation, the correction and adjustments are quicker [4]. As in all categories of software package, the quality and accuracy increase continuously, to meet the demand of industrials and researchers ([5],[6]). The proliferation of tools becomes problematic for the designer who has sometimes a multitude of functions that are not suitable for his application case.

The first step of our study consisted in listing all the comparable software and to select the comparison criteria. Then a list of indicators is proposed, in three major categories: degree of realism, functions and environment. Based on software use, literature searches [7] and technical reports ([8], [9], [10], for example), the table of indicator is filled and coded from text to a quinary format, in order to performed comparative analysis. The last part presents the results and the outlooks of the study.

2 DHM tools comparison : methodology

An exhaustive list of 32 commercially available 3D modeling software, computer programs used for developing a mathematical representation of any three-dimensional surface of objects was determined (step 1, Figure 1). A part of these tools defined as generic modelers (ie software allowing purely artistic entities modeling without real anthropometric approach) have been removed and a list of reachable human modelers was obtained (step 2, Figure 1). For example, Rhinoceros is a NURBS-based 3D modeling software, commonly used for industrial design, architecture, marine, jewelry design but not manikin design. It would have been inappropriate to keep them in the comparison. The same applies to the other generic modeler (not human dedicated design) as Blender, True SpaceMaya, 3D studio Max, Lightwave, (...), Pro/Engineer. The twelve DHM software selected for our study are (Figures 2-4) Jack (Siemens), Ramsis (Human Solutions), HumanCad (Nexgen Ergonomics), 3DSSPP (University of Michigan), Poser (Smith Micro), MakeHuman (freeware), Anybody (Anybody Technology), Catia (Dassault Systemes), Daz Studio (DAZ 3D Inc), Quidam (N-Sided), Santos (University of Iowa), Sammie (Sammie CAD Ltd).

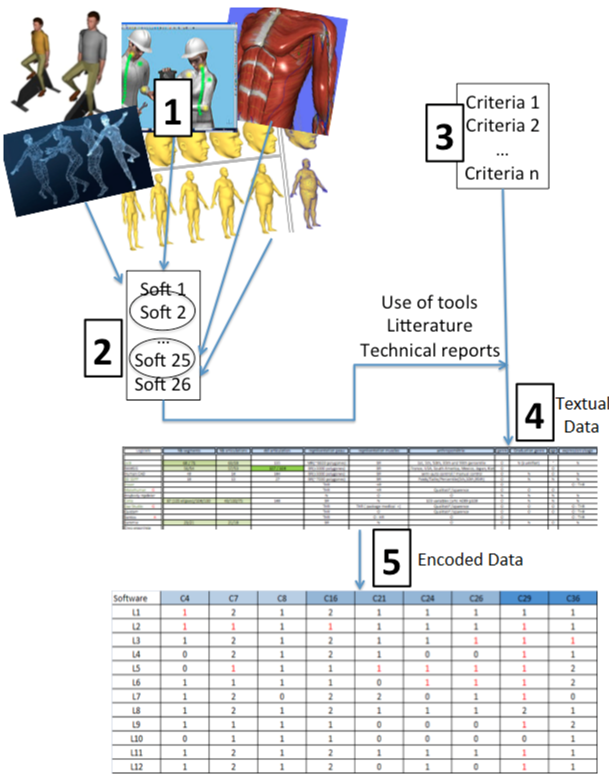

Figure 1: SYNOPTIC OF THE METHODOLOGY OF EVALUATION OF PRODUCTS

The step 3 (Figure 1) is the collection and selection of the differentiating criteria to evaluate the software.

3 Comparison table

3.1 Criteria

A list of indicators is defined to perform an objective comparison between all software (Table 1). To generate this

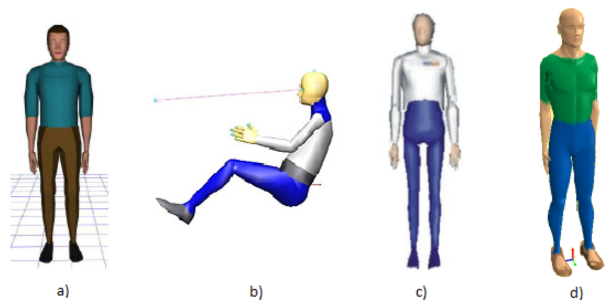

Figure 2: MANIKIN OF JACK (a), RAMSIS (b), HUMANCAD (c) AND 3DSSPP (d).

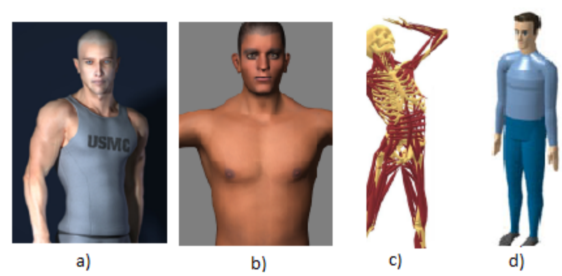

Figure 3: MANIKIN OF POSER (a), MAKEHUMAN (b), ANYBODY (c) AND DELMIA (d)

list, websites and forums about DHM tools are analyzed as technical manuals of Santos [11], Ramsis [12], Jack [13], 3DSSPP [14] for example. All the menus given a choice of functions are explored. The criteria are classified in 3 main classes:

• Class 1 : Degree of realism. This class is used to compare the reliability of the representation of the model and its movements or respect of human physical constraints, for example.

• Class 2 : Functions. This class is very important for ergonomic and fatigue studies. It is associated with existing functions in the software to perform some analysis on the virtual model (Reach envelop or Fatigue model for example).

• Class 3 : Environment. Includes criteria for the creation and manipulation of the environment available in software.

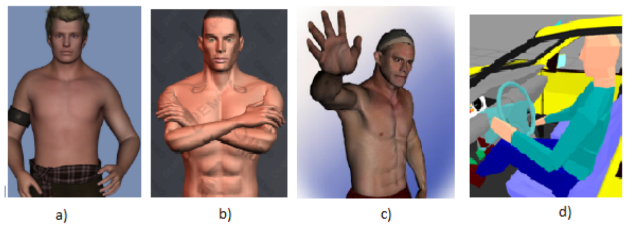

Figure 4: MANIKIN OF DAZ (a), QUIDAM (b), SANTOS (c) AND SAMMIE (d)

If the criteria are mostly obvious, definition is to be precise for others. *Physical limits* stands for taking into account the physical constraints of articulations as knee and elbow. The Gender graduation stands for the the evolution of body forms, more or less pronounced. *Complements* are all the personalization of the manikin with clothes or accessories, and their movement during an animation *(Dynamic of complements)*.

Few simplifications on the criteria were done. The number of degrees of freedom, joints and segments seemed confusing for a non expert-user. They have been gathered under the label *Accuracy joint chain*. Secondly, the difference between motion and animation is low and not always understood; the criteria were aggregated. Finally, in the data of environment, only the first, very important for ergonomic and the last one (essential to reach all trades and new applications) were kept. With the different transfer format, even if the software doesn't allow to create an environment, the manikin can be included in an existing one in another tool. It seems to us not primordial for this first study. The list of criteria has now 25 items.

3.2 Filling method (step 4, Figure 1)

A table containing software and the 25 criteria is built. Based on software use, literature searches, manual study and by contacting users of different softwares, each cell of this table is filled with textual data. This step, long and fastidious was led with rigor and completeness. The different scales were not pre-defined, ignoring a priori which information will be collected.

3.3 Coding of criteria (step 5, Figure 1)

To perform a comparative analysis, it is essential to formalize textual data contained in the table. Criteria (Table 1) were split in 3 categories. The first one is the binary criteria, answering yes or no for the presence of the function (b). The second class (q1) contains those evaluated on a 5 points scale, quantifying the criteria (0-criterion not satisfied, 1-criterion partially satisfied, 2-criterion moderately satisfied, 3-criterion rather well satisfied, 4-criterion completely satisfied). The last category is also a quinary scale about the precision of data (q2): for example, the skin representation can be inexistant (0), existing but not very modifiable (1) to fully configurable (5).

4 Compairison of tools

After coding data from text to a coded format for the entire comparison table, multivariate statistical analysis (Principal Components Analysis and Hierarchical Ascendant Classification) are used to perform a decision tree (Figure 5).

4.1 Principal Component Analysis

The Principal Component Analysis (PCA) is used to reduce the dimensions of the space allowing a representation of the proximity between individuals and variables and to find the underlying dimensions. The matrix was analyzed using standardized PCA. The two first factors represent 64,04% of variability. In our case (Figure 5), the first Principal Component is mainly composed of criteria based on the realism of the manikin, including its movements. Software are clearly in 2 groups on this axis: a first on the right side of the graph, composed of Poser/Daz/MakeHuman/Quidam, software allowing DHM simulation with an high quality graphics rendering. The left group has a littler graphical definition but with an higher number of analysis functionality. The second Principal Component is correlated to criteria based on analytic tools as collision detection or fatigue model. This confirms the intuitive classification of criteria performed.

On this first plan, Santos seems to be isolated, due to the fact that 15% of information stay on the 3rd principal

Table 1: CRITERIA OF THE 3 CLASSES

	Class 1 Degree of realism	**Class 2** Functions	**Class 3** Environment
1	Accuracy joint chain (q1)	Mannequin data base (q1)	Objects creation (b)
2	Physical limits (q1)	Posture data base (q1)	Intuitiveness of interface (q1)
3	Skin representation (q2)	Posture modification (q1)	
4	Muscles representation (q2)	Action/motion (q1)	
5	Anthropometry (q2)	Response to stress (b)	
6	Gender (b)	Static analyses (q1)	
7	Gender graduation (q1)	Dynamic analyses (b)	
8	Age (b)	Field of view (b)	
9	Face expression (b)	Reach envelop (b)	
10	Complements (q2)	Fatigue model (q2)	
11	Dynamic of complements (b)	Collision detection (b)	
12		Import/Export Format (q1)	

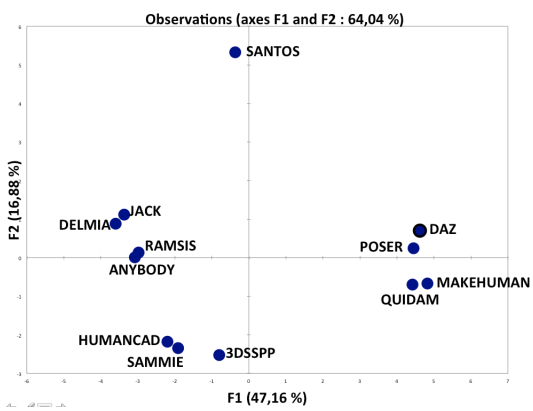

Figure 5: INDIVIDUALS REPRESENTATION INTO A TWO-DIMENSIONAL PLANE.

component not represented here. To precise this plan, we use the Hierarchical Ascendant Classification method.

4.2 Hierarchical Ascendant Classification

In order to provide a partition of the software and to define groups, similar from an analytic point of view, a hierarchical ascendant classification (HAC) [15] has been done. The principle of HAC is to build a hierarchical tree (dendrogram, Figure 6), which shows the level of each aggregation according to the dissimilarity between the products. The parameters of the method are the definition of the distance for computing the dissimilarities and the linkage rule, computed through the Ward criteria.

The dotted line represents the truncation and visualizes that three homogeneous groups were identified :

- C1 composed of Santos, Jack and Catia/Delmia,
- C2 composed of Anybody, 3DSSPP, Ramsis, HumanCad and Sammie,
- C3 composed of MakeHuman, Quidam, Poser and Daz.

The classification perform by the HAC appears to be consistent with the geometrical representation of the proximity between individuals implement by the PCA. Firstly, the four software on the right of the Figure 5 are grouped together in C3, divided in the two same subgroups Daz/Poser and Quidam/Makehuman resulting the proximity of these software. Secondly, the same couples Humancad/Sammie and Jack/Catia are found. In Figure 5, Ramsis and Anybody seem to be related (very close to each other), but not in the hierarchical tree. The cosine matrix of observations shows that the tools are strongly linked with the third component F3. That's why L2 and L7 are not directly interconnected on the hierarchical tree.

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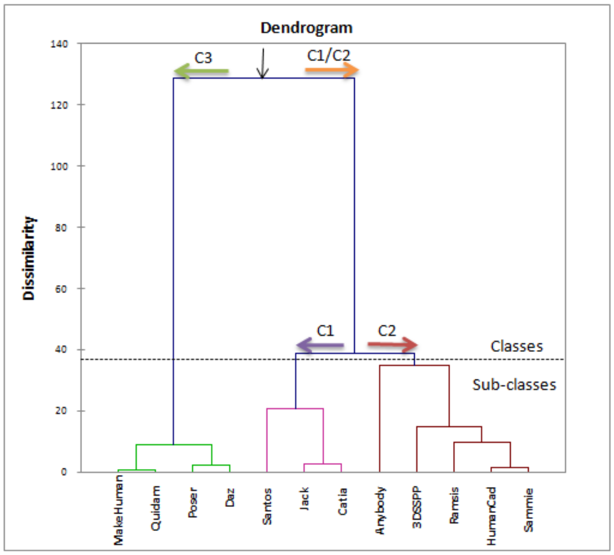

Figure 6: DENDROGRAM OF THE HIERARCHICAL ASCENDANT CLASSIFICATION

The same event arrive between Santos and Delmia/Jack. The most relevant representation seems to be or a 3D mapping from the PCA or, the dendrogram of the CAH. We will use the last cited, representation of the Hierarchical Ascendant Classification.

From the dendrogram, a protocol of choice of the best suited software to the expected use can be defined. The first step of the dissimilarity is performed between the class C3 and C1/C2 (Figure 6). The comparison of C3 link to C1/C2 on our criteria show a superiority of the performance of analysis (Table 1, column 2). The first question for the user will be about the analysis need. Then, the classes are divided in sub-classes. For example, in the class C3, two sub-classes are distinguished : the second group is autonomous to perform animations and motion capture (mocap), instead of the first group which have to export their digital human to another software allowing to perform animation and interaction with the avatars in mocap.

From the hierarchical tree and by identifying what are the main discriminating criteria, it is possible to define a protocol to determine from minimum questions, what is the best suited software to the expected use. Some criteria (variables) identified through the PCA and HAC are grouped together in the form of questions to guide quickly the search towards a specific group of software. Other criteria are then explicitly evaluated allowing accurate selection of the software. Five questions (regarding the "capacity to perform analysis", "realism of mannequin", "Animation of mannequin", "dynamic of analysis" and "human appearance of mannequin"), involving some discriminants criteria, allow to quickly select corresponding software. These questions are coded in a friendly interface following the algorithm given below.

Algorithm of selection

if Perform analysis ="no" **then**
  if Animation="no" **then**
    soft = MakeHuman or Quidam
  else soft = Poser or Daz Studio
  end if
else if Animation="yes" **then**
    if Realistic="yes" **then**
      soft = Santos
    else soft = Jack or Catia
    end if
  else if Human appearance="yes" **then**
      soft = Anybody modeler
      else if Dynamic analysis="yes" **then**
      soft = Ramsis or 3DSSP
        else soft = Sammie or HumanCad
          end if
        end if
  end if
end if

where stands
Perform analysis for "Do you need functions to perform analysis on the virtual mannequin (eg static analysis, field of vision, collision detection, reach envelop...) ?",
Realistic for "Do you need a realistic virtual mannequin with an high graphical rendering ?",
Animation for "Do you need to perform animation and mocap inside my software ?"
Dynamic analysis to "Do you need to do dynamic analysis
Human appearance seems obvious.

5

These simple questions can be answered by the designer to guide him in his choice of software.

5 Conclusion and perspectives

This paper presented a comparison of digital human modeling software allowing to perform a decision making tools to help the designer to choose his software. Twelve digital human modeling software have been presented and compared. From a table including characteristics of software through al list of 25 comparison criteria, Principal Components Analysis and Hierarchical Ascendant Classification were used to build a decision tree. The procedure to select the most adaptable soft is finally exposed. The next step of the project is to guide the selection by visual perception, not only questions. In the case of recommender for Design Human Modeling software, we want also to improve the acquisition of anthropometric data, extracted from pictures for example. The designer may present situations that he would like to represent, and after interpretation of images variations(postures, ergonomics, anthropometry ...) software would be advisable with a manikin to customize.

The human modeling is essential in the lifecycle of the product, allowing a very good communication between all the actors of the life of product. Integration of an adapted DHM tools in the product life cycle allows to perform both a more efficient design and more sustainable products. The aim of the presented procedure is the conception of a tool allowing to the designer to quickly determine what are the types of solutions that best suit his needs. In our study, the tools are dedicated to helping the designer to find the most suitable software. However, the methodology can be adapted to all kinds of applications, for example in the design of products. Indeed, software of our study may be replaced by a sample of a product randomly generated (Monte Carlo's method...) and also evaluated using criteria (height, width, color, texture, materials...). Thus, using our method, the discriminating criteria may be identified and automatically encoded in the decision making tools allowing to offer to the designer a sample of shapes adapted to their needs, by answering some questions.

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